SPECIAL ARTICLES, NOTES, AND EXTRACTS.

INFLUENCE OF TEMPERATURE AND MOISTURE UPON THE RATE OF GROWTH OF TOBACCO.

By GEORGE N. COFFEY. Dated Washington, D. C., August 28, 1907.

The Bureau of Soils of the United States Department of Agriculture for several years conducted experiments with tobacco under shade at Tarriffville, Conn. A recent bulletin of this Bureau, No. 39, entitled "Effect of Shading on Soil Conditions", gives the results of some observations which were made during the year 1905. The temperature and relative humidity of the air, the amount of rainfall, the moisture content of the soil and the height of a number of plants were determined daily. All of these observations, except rainfall, were made both inside and outside of the tent.

These observations showed that the effect of the tent is to conserve the moisture in the soil, to increase the temperature and relative humidity of the air, to reduce the velocity of the wind, to make a taller, larger, more rapid, and earlier growth of the plant, but to diminish the yield per acre by from 100 to 300 pounds; thus showing that the leaves were thinner or had a more delicate texture when grown under shade than when grown outside the tent.

Table 1, compiled from data taken inside one of the tents, shows the mean temperature and relative humidity of the air, the moisture content relative to saturation of the first 9 inches of the soil, the average height of the plants, the average amount of growth, and the average percentage of growth for five plants. These percentages represent the ratio of the daily growth divided by the average height on the earlier date. While the plants were small the measurements were taken to fractions of an inch, but later the fractions were omitted.

TABLE 1.—*Measurements of tobacco plants and conditions surrounding them; mean temperature, relative humidity, and soil moisture in the shade of the tent.*

Date.	Mean temperature.	Relative humidity.	Moisture in soil.	Average height of five plants.	Average daily amount of growth of plants.	Average daily percentage of growth.
1905.	°F.	Per cent.	Per cent.	Inches.	Inches.	Per cent.
June 15	73.5	.....	16.5	1.62	0.38	23.5
16	75.0	.....	16.2	2.00	0.4	20.0
17	77.0	.....	16.2	2.4	0.7	29.1
18	75.0	.....	15.4	3.1	0.65	20.9
19	58.5	.....	14.9	3.75	0.45	12.0
20	60.5	.....	15.4	4.2	0.45	10.7
21	67.0	.....	15.5	4.65	0.4	8.6
22	76.5	.....	17.1	5.05	1.05	20.8
23	73.5	78.0	16.5	6.1	1.1	18.0
24	64.0	70.0	15.8	7.2		
25	74.5	75.0	16.4	.....	0.97	13.5
26	71.0	74.0	15.3	.....		
27	61.0	73.0	15.5	10.1	0.55	5.4
28	65.5	73.0	14.8	10.65	1.35	12.8
29	67.5	70.5	15.3	12.00	1.1	9.2
30	74.5	70.0	13.7	13.1	1.0	7.6
July 1	72.0	79.0	15.6	14.1	1.5	10.6
2	68.0	85.5	15.4	.....		
3	75.0	71.0	15.3	17.1	1.7	9.9
4	74.5	70.0	14.9	18.8	2.6	13.8
5	75.0	75.0	13.5	21.4	2.2	10.3
6	79.0	76.0	13.9	23.6	1.6	6.8
7	79.0	76.0	14.0	25.2	3.4	13.4
8	82.0	76.5	13.1	28.6	2.5	8.9
9	81.0	72.5	13.0	.....		
10	80.0	74.5	12.7	33.6	3.2	9.8
11	82.5	76.0	13.7	36.8	4.0	10.8
12	84.0	75.0	13.4	40.8	3.2	7.8
13	81.0	72.0	12.4	44.0	3.5	8.0
14	79.5	70.5	11.8	.....		
15	68.0	71.0	13.9	51.0	3.3	6.5
16	77.0	68.5	13.9	.....		
17	83.0	76.5	14.1	57.6	4.2	7.3
18	83.0	71.0	13.8	61.8	4.6	7.4
19	79.5	75.0	13.5	66.4	3.2	4.8
20	72.0	71.5	13.4	69.6	3.2	4.6
21	67.0	71.0	13.4	72.8	3.2	4.4
22	70.0	72.0	13.4	76.0	.....	.....

While there are several unfortunate breaks in the record it furnishes some interesting data for a study of the cause of the variation in the growth of the plants from day to day. This variation can be determined by subtracting the height of the plant one day from that on the following day. After the first of July the measurements of the individual plants were not made closer than 1 inch, and this may account for some irregularities in the growth of the plants which are difficult otherwise to explain.

There are a number of factors which may influence the rate of growth of the plant, some of which do not appear in the data given in the bulletin above quoted. Among these may be mentioned the temperature of the soil, and the amount of sunshine, two factors which certainly have an important influence. The factors which were studied in the present case were the temperature and the relative humidity of the air, and the percentage of moisture in the soil.

TEMPERATURE OF THE AIR.

From a study of the data here given it appears that in this case the variation in the temperature had a marked effect upon the growth of the plant. Fig. 1 is a diagram which shows this in a graphic way.

The solid line represents the mean temperature, while the dotted line shows the amount of growth in inches from day to day as obtained from the average of the five plants. Where only the total growth for two or more days is known the daily average is indicated by a single dot in the center of the gap, the total amount of growth being divided by the proper number. From June 15 to 24 the growth follows in a rather marked degree the changes in the temperature, increasing with the rise and decreasing with the fall in temperature. The influence of the high temperature on the 17th and 18th of July is also quite evident, the plants showing a marked increase in growth with the rapid rise of the temperature. There are, however, several important divergencies in the two lines, the most striking being on June 29 and 30 and July 6. In general it may be said that the variation was greater during the middle period of the observations. It should be added that another set of five plants grown under shade and also a third set grown outside the tent did not show such an irregularity, and it may be possible that there was some mistake in the measurements or some variation in the time of making them that would account for this.

It will be seen from the diagram that the absolute amount of growth of the plants increases as the plants become larger, whereas the percentage of growth becomes smaller, so a comparison based upon the percentage of growth rather than on the amount is in some respects more satisfactory. The measurements during the first period of observation were taken to fractions of an inch, and here the relation between the percentage of growth and the temperature is most marked.

In general the percentage of growth followed the temperature. The influence of a marked drop in temperature is always shown by a decrease in the growth of the plant and this appears to affect the plant for several days afterwards. Take, for example, the decided drop in temperature from the 18th to the 19th of June, when there was a fall of 16.5° in the mean temperature from one day to the next. The percentage of growth of the plants decreased. From the 19th to the 20th there was a rise of 2° in the mean temperature, but a further decrease, tho slight, in the percentage of growth. Likewise from the 20th to the 21st the mean temperature rose 6.5°, but the rate of growth was slightly less than on the preceding day. From the 21st to the 22d there was a further rise of 9.5° and the growth increased 12.2 per cent. Thus it would seem that it took the plants two days to recover from the effect of the marked drop in temperature on the 19th. When, however, they had recovered they leapt up with a bound under the marked rise in temperature which had taken place. With the temperature at its former level the percentage of growth also became practically the same.

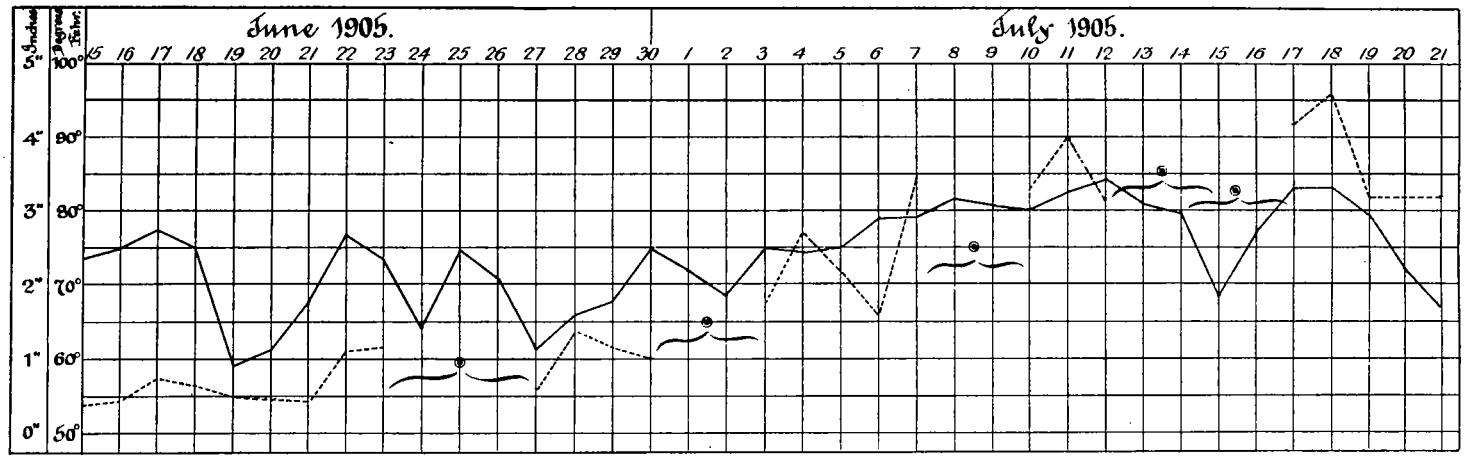

FIG. 1.—Daily temperatures and growth of tobacco plants. Solid line, observed mean daily temperature, Fahrenheit. Dotted line, observed average daily growth of five plants, in inches.

In order to show more definitely the influence of temperature upon the growth of the plants it will be best to compare the percentage of growth on the days with highest and lowest temperatures. Since the percentage of growth decreases so much and the amount of growth increases so much as the plants become larger, it will be well to divide the observations into three shorter periods, roughly where there are breaks in the daily observations. In the first place we will compare the mean percentages of growth on days falling in different classes as to temperature:

Days with mean temperature—	First period, June 15–23.		Second period, June 27–30, July 3–7.		Third period, July 11, 12, 17–21.	
	Number of days.	Mean rate of growth.	Number of days.	Mean rate of growth.	Number of days.	Mean rate of growth.
°		*Per cent.*		*Per cent.*		*Per cent.*
80 or higher.	0	.....	0	.....	4	8.6
70–79.9	6	22.0	6	10.3	2	4.7
60–69.9	2	9.6	3	9.1	1	4.4
Lower than 60	1	12.0	0	.....	0	.....

In this table in the second period the 1st and 2d of July were omitted, as were also the 13th, 14th, 15th, and 16th of July in the third period, owing to the omissions in the original records.

In every instance the mean percentage of growth decreases, except for the day when the temperature was lower than 60°; this occurred on only one day (June 19), altho the following day the mean temperature was only 60.5°. Probably the effect of the marked drop in temperature on the 19th was not fully felt until next day.

The following table shows the percentages of growth during the hottest and the coolest day of each period:

	First period.	Second period.	Third period.
	Per cent.	*Per cent.*	*Per cent.*
Hottest day	29.1	10.1	7.8
Coolest day	12.0	5.4	4.4

This table indicates very plainly the marked effect of the temperature. In the second period there were two hottest days which had the same mean temperature, and the figure given is the mean of these two days. While there is a considerable difference in the growth on these days (July 6 and 7) both were higher than that of the coolest day.

Another method of comparison is by taking the mean of the three hottest and three coolest days of each period, and this is shown in the following table:

	First period.		Second period.		Third period.	
	Mean temp.	Mean rate of growth.	Mean temp.	Mean rate of growth.	Mean temp.	Mean rate of growth.
	°	*Per cent.*	°	*Per cent.*	°	*Per cent.*
3 hottest days	76	23.3	78	10.1	83	7.5
3 coolest days	62	10.4	64	9.1	72	4.6

Here, as in the above tables, there is a decrease in growth with a fall in temperature.

The mean percentage of growth for all days with a temperature less than the mean temperature (73.8°) of the entire period (exclusive of those days upon which no observations were taken) is 10.8, while that for the days with a greater mean temperature is 12.5. The mean temperature of the former days is 66.6°, while that of the latter is 79.3°. A difference of 11.7° in temperature has therefore produced a difference of 1.7 per cent of growth, or 0.145 per cent of growth for each degree change in temperature.

HUMIDITY OF THE AIR.

In this connection we will now make a comparison of the percentage of growth with the relative humidity of the air. The following table shows for the second and third periods the mean percentage of growth on the three days having respectively the highest and the lowest relative humidities. The first period will have to be omitted, as the humidity was not then determined.

Mean percentage of growth on three days of—	Second period.	Third period.
	Per cent.	*Per cent.*
Highest humidity	10.2	7.6
Lowest humidity	10.2	5.5

In the second period it would appear that the relative humidity had no influence whatever upon the growth. The third period, however, seems to indicate that a high humidity is more favorable to the rapid growth of the plant.

If we consider the growth on the days having a humidity below the mean (73.9 per cent) for the two periods, we find that the percentage stands 8.9 for the days with a higher humidity and 8.3 for those having a lower. This is a very small difference, but would seem to indicate that a high humidity is slightly more favorable for rapid development of the plant. It should be noted, however, that the days with the greatest humidity were more often also days of high temperature, and it does not seem improbable that the slight difference shown above is due to this factor instead of to the greater humidity.

In this connection a comparison of the percentage of growth on days having the same temperature but different humidity with that for other days on which the conditions were reversed will be especially instructive. Let us take for example the 3d and 5th and 17th and 18th of July. The mean percentage of growth on the 3d and 18th, the days having relatively the lower humidity, was 8.6 per cent, while the 5th and 17th showed only 8.8 per cent. This comparison would seem to show that the greater humidity produced the greater growth, but the very reverse would have been found if we had taken the 4th instead of the 3d. On the 27th and 28th of June the humidity was the same, while the temperature was different, and this is practically true for the 29th and 30th of June and also the 20th and 21st of July. For the first two days the growth was greater on the day of higher temperature; for the second two days the reverse is found, while the third pair is similar to the first. The mean for the three days of relatively lowest temperature is 6.3 per cent, while for the three highest it is 8.3 per cent. This would indicate that the temperature is the most important factor in determining the rate of growth.

MOISTURE OF THE SOIL.

The following table shows the mean percentage of growth on the three days with greatest and least moisture content of the soil:

Mean percentage of growth on three days of—	First period	Second period.	Third period.
	Per cent.	*Per cent.*	*Per cent.*
Greatest moisture	20.5	8.2	8.5
Least moisture	14.5	8.2	8.6

The figures for the first period would seem to indicate that the greater moisture content was decidedly more favorable, but it should be noted that the days with lowest moisture content coincided with days of extremely low temperature, which doubtless accounts for the marked difference of growth. The other two periods show practically no difference in growth, and we seem justified in concluding that the variation in moisture here had no influence in determining the rate of growth. However, the moisture never fell lower than 11.8 per cent, and this quantity was doubtless sufficient for the needs of the tobacco plants under existing conditions as to sunshine, temperature, and wind; so that much greater changes in the moisture content must be made before its influence can be determined.

SUMMARY.

To sum up: The data would indicate that the moisture in the soil was always sufficient in quantity, and that the relative humidity of the air had very little if any influence upon the rate of growth, but that a decided rise or fall in temperature was followed by an acceleration or diminution, respectively, in the rate of growth of the plants. When, however, the change in temperature was small there were other unknown factors that had a more important influence. If the measurements had been taken to one-sixteenth of an inch, a closer relation might have been shown here also.

STUDIES OF FROST AND ICE CRYSTALS.

By WILSON A. BENTLEY. Dated Jericho, Vt., May 28, 1906. Revised July, 1907.

PREFACE.

(1) Object of this memoir.

This paper is intended as a companion memoir to my "Studies among the snow crystals during the winter of 1901–2", etc., published by the Weather Bureau in 1902.[1] It is my hope that the present study may serve to reveal the forms, structure, life history, and general relations of the frost and ice crystals even more fully than did the memoir on snow crystals.

The forms that occur among the frost, ice, hoarfrost, window-frost, and window-ice crystallizations are hardly less beautiful, varied, and interesting than are those other marvelously beautiful crystals from cloudland that we call snow. The great beauty and diversity of the frost and ice crystals early attracted the author's attention and study, and his first photomicrographic work, while he was yet in his "teens", was directed to this subject. He secured his first photomicrographs of frost crystals in December, 1884. This work has been continued by him, mostly at his home in Jericho, Vt.,[2] at intervals ever since. A few, and sometimes many, forms were photographed each winter, so that now his collection numbers over seven hundred specimens, of which no two are alike.

His endeavor has been not only to learn all possible regarding their manner of formation, habits of growth, and the conditions under which various varieties form and develop, but also to secure a fairly complete series of photographs that should preserve for the student the semblance of each and every type and species of crystal of frost and ice. This has proved to be a task of no small difficulty, requiring a vast amount of time and necessitating no little expense. Some types of frost and ice proved to be very difficult subjects for photography, and in some cases it became necessary to construct special apparatus in order to secure satisfactory photographs. All the half-tone reproductions are made from original photographs of natural crystals. In this connection it is perhaps well to state that the author's photographic work on both snow and frost crystals has been carried on entirely at his own personal expense, and, as is commonly the case when investigations must be conducted solely at private expense, a lack of means has greatly hampered the work. This must be his apology for a lack of excellence in the technique of some of the photographs. Many of them could have been greatly improved by recopying.

The author hopes that this memoir will not only impart to others the knowledge that he has gained, but will call the attention of all lovers of nature to this hitherto much neglected, yet most beautiful, subject. The publication at this time, with the half-tone pictures here reproduced[3], is due to the kindly appreciation of the Chief of the Weather Bureau and the Editor of the MONTHLY WEATHER REVIEW.

It need hardly be said that the half-tones, numerous tho they be, illustrate only a few of the almost infinitely varied individual forms of the frost and ice that occur in nature. They will but give a glimpse into the beauties of this fairy realm of snow, frost, and ice.

In view of the ease with which many varieties of frost and ice crystals can be obtained it is thought best to give a brief sketch of the methods that were, or that may be, employed, in securing photographs of such objects, in the hope that this information may be helpful to many.

(2) Methods employed.

Two distinct methods may be employed in this photographic work—one by oblique light and low magnifying powers, using an ordinary one-fourth size portrait lens or similar objective and extension camera; the other by direct transmitted light, using a three-fourths or one-half inch microscope objective, for higher magnification (15 to 30 diameters.) The great majority of the window-frost, and many window-ice crystals are perhaps best secured by the former oblique-light process. Many of the large feathery window designs require no extension camera; an ordinary view camera suffices equally well.

[1] See Monthly Weather Review, Annual Summary, 1902, Vol. XXX, p. 607–616 and Plates I–XXII.

[2] On a farm 16 miles east-northeast of Burlington, midway between Mount Mansfield and Camels Hump, 1500 feet above sea level—latitude 44° 30′ north, longitude 73° 00′ west.

[3] The half-tones illustrating this memoir will be published later.—EDITOR.